

Mosquito Control Plan

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Mosquito Control Plan

F.1 Introduction

This plan addresses monitoring mosquito populations, the surveillance of mosquito-borne pathogens that cause diseases in human and wildlife, and the implementation of a treatment program to control mosquitoes at the Species Conservation Habitat (SCH) ponds and sedimentation basins at the outflows of the Alamo River or New River into the Salton Sea. The plan addresses human health concerns and is modeled after the Mosquito Monitoring Program for the Sonny Bono Salton Sea National Wildlife Refuge, Calipatria, California (United States Fish and Wildlife Service [USFWS] 2005). Monitoring activities would be used to locate mosquito life stages (larvae, pupae, and adults), estimate their abundance and determine species composition for the purpose of making treatment decisions. Disease surveillance would be used to detect the presence of mosquito-borne disease as part of a state-wide program. Mosquito treatments would be used to reduce the abundance of mosquito populations and associated mosquito-borne disease risk. Vector population and pathogen monitoring are fundamental components of any mosquito management program and are necessary for making informed decisions related to cost-effective mosquito management.

Mosquitoes are considered an annoyance because of their biting, and many species are known vectors of pathogens that cause serious diseases in California. Of the mosquito-borne viruses known to occur in California, western equine encephalomyelitis virus (WEE), St. Louis encephalitis virus (SLE), and West Nile virus (WN) have caused significant outbreaks of human disease (California Department of Public Health [CDPH] 2009, 2011). WEE and WN have been detected in adult mosquito samples from the Sonny Bono Salton Sea National Wildlife Refuge, which is adjacent to the SCH ponds and sedimentation basin associated with the Alamo River.

WEE tends to be most serious in very young children, whereas elderly people are most at risk from SLE and WN (CDPH 2009). Both WEE and WN can cause serious diseases in horses and emus, and WN kills a wide variety of endemic and imported birds. Birds are the primary reservoirs of the viruses and differ among species in the amplification of viruses within the bloodstream and susceptibility to the viruses. Humans and horses are dead-end hosts for the viruses; although the effects of a virus infection can be severe, titers of the virus in the bloodstream are insufficient to reinfect the mosquito vectors. With the exception of available vaccines to protect horses against WEE and WN, there are no known specific treatments or cures for diseases caused by these viruses (CDPH 2009). At the present time, mosquito control is the only practical method of protecting the people of California from mosquito-borne diseases.

The mosquito species potentially utilizing the SCH habitats as developmental sites for the immature stages of the mosquito life cycle include *Culex erythrothorax*, *Cx. tarsalis* and *Aedes vexans*. *Culex tarsalis* is the primary vector of WEE, SLE and WN in rural settings of California (CDPH 2009). *Cx. erythrothorax* and *Aedes vexans* may also contribute to disease transmission (Goddard et al. 2002). These mosquito species are targeted for monitoring and treatment.

The proposed habitats are located in Imperial Valley adjacent to the Salton Sea at the outflows of the New River and Alamo River. Within 30 miles of the SCH are the communities of Niland¹ (population 1,329), Calipatria (population 7,623), Westmorland (population 1,620), Brawley (population 22,438), Imperial (population 12,162) and El Centro (39,902); and another 10,000 people live in the unincorporated region. Surrounding land use includes farming, recreational camping and hunting, and geothermal power generation.

F.1.1 Mosquito Control Methods

Larval mosquito control has three key components: environmental management, biological control, and chemical control (Knight et al. 2003; CDPH 2008, 2011). Environmental management includes the measures that decrease habitat availability or suitability for immature mosquitoes. Environmental management includes the design and management practices applicable to the SCH Project and may also include water-level management; environmental alterations that reduce standing water through evaporation, percolation, recirculation, or drainage; and vegetation management.

Biological control uses natural predators, parasites, or pathogens to reduce immature mosquito numbers. No efficacious biological control agents are available for adult mosquitoes. Incorporation and management practices to enhance populations of mosquito-eating fish and naturally occurring insect predators can be important adjunct Integrated Vector Management (IVM) measures that significantly reduce mosquito production. While the mosquitofish, *Gambusia affinis*, is the most widely used biological control agent in California, many of the native fish species merit consideration as biological control agents for mosquitoes. The fish fauna in the agricultural drains and other aquatic habitats surrounding the Salton Sea include several small, introduced and native fish species (Saiki et al. 2010), including the desert pupfish (*Cyprinodon macularius*), that consume immature mosquitoes (Walters and Legner 1980; Walton 2007). One goal of the SCH Project is to include fish in the food web of the habitat ponds. An ancillary benefit of managing the habitat to support healthy fish populations is the planktivorous life stages and species are likely to assist mosquito control where mosquito larvae occur in the ponds or in other component habitats.

Chemical control for the aquatic stages of the mosquito life cycle includes non-persistent biological agents. The non-persistent biological agents include microbial control agents, such as *Bacillus thuringiensis* subsp. *israelensis* (*Bti*) and *Bacillus sphaericus*, and insect growth regulators (IGRs), such as methoprene. The *Bacillus* produce protein precursors during sporulation that, following ingestion by the mosquito larva, disrupt the integrity of mosquito digestive tract and interfere with the ability of the larva to osmoregulate. In California, the microbial agents are used most frequently to reduce populations of mosquito larvae. The IGR mimics an insect-specific hormone that prevents immature mosquitoes from developing into adults. Other control agents include chemicals (e.g., monomolecular surface films, light-grade oils) that alter the surface tension of the water drowning the immature stages of mosquitoes and insecticidal chemicals. These surface-tension agents are used rarely but are used against pupae which do not feed and consequently do not ingest the microbial agents. Organophosphate pesticides such as temephos are rarely used in California to control the immature stages of mosquitoes because of their potential impact on nontarget organisms and the environment.

F.2 Monitoring

It is expected that the SCH ponds would not be conducive to mosquito production because the configuration of the ponds includes a large proportion of the surface area with open water at a depth > 2 feet. Open water should reduce the survival of immature mosquitoes because of disturbance and drowning

¹ Populations are based on the 2005-2009 American Community Survey 5-Year Estimates (United States [U.S.] Census Bureau 2011).

caused by wind-driven waves and high susceptibility to predators. The SCH ponds at the high end of the range of operational salinities are predicted to be too salty for significant mosquito production and colonization by wetland plants. If mosquito production occurs in the SCH ponds, it is likely to be limited to the shallow zones of the upslope periphery of the pond and maybe the berms, if aquatic vegetation and/or inundated grasses (i.e., *Distichlis*) colonize the shallow water and berms. The width of this area may be only 3 feet to 6 feet (1 to 2 meters) which represents only 0.6-1.1 percent of the surface area of a 100-acre pond. If vegetation is found along the periphery of the sedimentation pond, then monitoring for larval mosquito populations would occur at natural openings in vegetation.

The ponds could be managed at a salinity ranging from 20 parts per thousand (ppt) to 40 ppt, which would reduce the potential for vegetation to grow in the ponds because the higher salinities exceed the tolerances of most freshwater macrophytes. Salinities at the lower end of the management range, however, may not limit macrophyte colonization. Vegetation management in the low salinity ponds may be required to reduce or eliminate conditions conducive to mosquito production.

The primary mosquito vector of encephalitis viruses in the Imperial Valley, *Culex tarsalis*, is capable of surviving and developing to adulthood successfully in salinities up to 70 percent (24.5 ppt) of full-strength sea water (Bradley 1987; Garrett and Bradley 1987). While laboratory studies using larvae collected from the Central Valley of California indicated that *Cx. tarsalis* production would be greatly reduced at salinities > 24.5 ppt, *Cx. tarsalis* larvae have been collected from the periphery of the Salton Sea (personal communications, T. J. Bradley 2011; H. Lothrop 2011; and W. K. Resien 2011). The salinity of the Salton Sea at the time these larvae were collected is estimated to have been 39 ppt. The occurrence of larvae of a brackish-water mosquito species (Bradley 1987) of public health importance in the Salton Sea raises concern that mosquito production may be possible across the entire range of salinities of the SCH ponds.

Immature (larvae, pupae) mosquito abundance is monitored using dippers. A dipper is a long-handled ladle that collects a 500 ml water sample from pools potentially serving as mosquito sources. The water sample is evaluated for the presence of larval mosquitoes and when mosquito larva are present, 'dip-counts' are used as a measure of immature mosquito abundance. Captured mosquitoes are then identified to species by skilled technicians.

Adult mosquitoes are monitored using carbon dioxide-baited traps (CO₂-baited suction traps). The traps are baited with 1-2 kilograms of dry ice that attracts adult mosquitoes as it sublimates. An electric fan forces the adult mosquitoes into a collection container. Trapped mosquitoes are enumerated, identified and processed for mosquito-borne disease detection in a laboratory. Six traps are proposed for deployment adjacent to the SCH habitats. A minimum of three traps (6 traps total) should be deployed at each group of SCH ponds at the outflows of the New River or the Alamo River, depending on the selected alternative. Traps should be placed at the western and eastern ends of each of SCH pond systems and at a site approximately equidistant between the traps on the east-west transect. Alternative placement of the traps could be carried out after operation of the SCH ponds begins if better trapping sites become evident. At least one CDC style CO₂-baited trap should be deployed at each sedimentation basin. More than one trap per each component would increase the reliability of the numbers for adult mosquito population monitoring and provide a collection if one of the traps were to fail on a particular night. Labor and time constraints, as well as funds budgeted for monitoring, would determine the extent of sampling.

Monitoring for immature and adult mosquito populations would occur from April through October. Monitoring activities may occur at any time during the day. Mosquito monitoring crews may require one half to one full day to conduct monitoring activities and the frequency would depend on mosquito activity which is in turn dependent on environmental conditions such as temperature. Monitoring frequency may range from twice per month to once every week.

F.3 Treatment

Treatment of larval mosquito populations would be focused on larvae occurring in vegetated wetland habitats that may develop along the periphery of the SCH ponds and the sedimentation basins. Only those areas where monitoring has shown that larval average dip counts for *Culex* have reached or exceeded one larva per dip would be targeted for treatment. However, specific areas treated and the extent of treatment would vary from year to year depending on mosquito populations and environmental conditions.

Larval thresholds may be reached or exceeded at any point during the monitoring season from April through October, thereby resulting in treatment. Larval treatments may occur anytime during the daylight hours. The frequency of larval treatments would depend on larvicide persistence, rate of post-treatment mosquito recovery, and species specific seasonal development. Larval treatment frequency may range from once per seven days to once per month.

The larvicides proposed to be used are Vectolex CG and Vectobac 12AS. Vectobac CG contains the active ingredient *Bacillus sphaericus*. Vectobac 12AS contains the active ingredient *Bacillus thuringiensis* subsp. *israelensis* (*Bti*). *B. sphaericus* and *Bti* are naturally occurring anaerobic spore forming bacteria mass produced using modern fermentation technology. Formulated *B. sphaericus* and *Bti* products contain bacterial spores and protein endotoxins. The endotoxin is activated in the alkaline midgut of susceptible insect species with subsequent binding to protein-specific receptors resulting in a lethal response (Lacey and Mulla 1990; Walton et al. 1998; Knight et al. 2003). Therefore, these products must be ingested by the target insect to be effective. Mosquito pupae and adults are not affected because they do not ingest the product.

Vectolex CG is a granular formulation consisting of 7.5 percent active ingredient. It would be applied at a rate of 5.0 to 20.0 pounds of formulated product per acre. Vectobac 12AS is a liquid formulation with 1.2 percent active ingredient. It would be applied at a rate of 0.25-1 pt/acre. Either product may be applied as a spot treatment to small areas or broadcast over larger areas by ground and/or aerial (fixed wing or helicopter) equipment. Ground-based equipment includes gas powered broadcasters affixed to a backpack, an all-terrain vehicle, or truck. The application would be done by the County Public Health Department or their contractor.

Treatment of adult mosquitoes would be initiated only if larval treatments failed to prevent adult mosquito populations from reaching and/or exceeding 25 adult *Culex* in any single trap or 5 adult *Culex* per trap in one night. Treatment may occur in riparian and upland habitats near or adjacent to the SCH Project, but not directly over the water. The specific areas treated and the extent of treatment would vary from year to year depending on mosquito populations and environmental conditions. Adulticide treatments have the potential to drift beyond the targeted treatment area.

Treatment thresholds should reflect changes in mosquito-borne disease threats. The California Mosquito-borne Virus Surveillance and Response Plan (CDPH 2009) provides a semi-quantitative measure of virus transmission risk to humans that can be used by local vector control agencies to plan and modulate control activities. This plan can be used to develop management and vector control activities at the SCH Project site. Table G-1 provides a response matrix that is a function of the mosquito-borne disease health threat.

Adult thresholds may be reached or exceeded at any point during the monitoring season from April through October, thereby resulting in treatment. Adult mosquito treatments would occur during early morning or evening hours. The frequency of adult mosquito treatments would depend on the rate of post treatment recovery and species specific seasonal development. Adult mosquito treatment frequency may range from once per five days to once per month.

The proposed adulticide is Pyrenone 25-5. Pyrenone 25-5 consists of 5 percent natural pyrethrins and 25 percent piperonyl butoxide. Natural pyrethrins are extracted from chrysanthemum plants and consist of a mixture of pyrethrin-I, pyrethrin-II, cinerin I and II, and jasmolin I and II (Extension Toxicology Network 1996). The natural pyrethrins are non-systemic contact poisons which quickly penetrate the insect nervous system causing paralysis and subsequent death (Extension Toxicology Network 1996; Tomlin 1997). A few minutes after application, the insect cannot move or fly away. However, the pyrethrins are swiftly detoxified by enzymes in the insect and thus, exposed insects can recover. To delay the enzyme action so a lethal dose is assured, commercial products are formulated with the synergist piperonyl butoxide (PBO) to inhibit detoxification (Tomlin 1997).

Table F-1 Mosquito-Borne Disease Health Threat and Response Matrix

Current Conditions		Threat Level	Response
Health Threat Category ¹	SCH Mosquito Populations ²		
No documented existing or historical health threat/emergency	No action threshold	1	Remove/manage artificial mosquito breeding sites such as tires, tanks, or similar debris/containers.
Documented historical health threat/emergency	Below action threshold	2	Response as in threat level 1, plus: allow compatible monitoring and disease surveillance. Consider compatible nonpesticide management options to reduce mosquito production.
	Above action threshold	3	Response as in threat level 2, plus: allow site-specific compatible larviciding of infested areas as determined by monitoring.
Documented existing health threat. Disease found in sentinels (chicken), equines, wildlife, mosquitoes or humans.	Below action threshold	4	Response as in threat level 2, plus: increase monitoring and disease surveillance.
	Above action threshold	5	Response as in threat levels 3 and 4, plus: allow compatible site-specific larviciding, or adulticiding of infested areas as determined by monitoring.
Officially determined existing health emergency	Below action threshold	6	Maximize monitoring and disease surveillance.
	Above action threshold	7	Response as in threat level 6, plus: allow site-specific larviciding, and adulticiding of infested areas as determined by monitoring.
<p>1. Health threat/emergency as determined by Federal and/or State/local public health authorities with jurisdiction inclusive of SCH boundaries and/or neighboring public health authorities.</p> <p>2. Action thresholds represent mosquito population levels that may require intervention measures. Thresholds would be developed in collaboration with State/local public health authorities and vector control districts.</p>			

Pyrenone 25-5 is a liquid formulation that would be applied using a rate of 0.0025 pounds active ingredient per acre. Treatments would be made using ultra-low volume (ULV) sprays that incorporate small amounts of the active ingredient as very fine droplets (10-30 micrometers in diameter). This small

droplet size allows the spray to drift for a relatively longer period of time compared to larger droplets, and the small size delivers an appropriate dose of the pesticide to kill an adult mosquito. Drift is a necessary component of adulticiding because these sprays are most effective on flying insects. For this reason, adulticide applications generally occur in the evening or early morning hours when the majority of mosquito species are most active. Adulticides may be applied by truck-mounted sprayers or applied aerially by helicopter or fixed-wing aircraft. Pyrenone 25-5 will not be applied directly over water. The application would be done by the County Public Health Department or their contractor.

F.4 Availability of Resources

Significant service staff resources may be needed for environmental compliance responsibilities. The agency/agencies responsible for the mosquito-related activities has/have yet to be determined. A vector control agency/consultant/staff would be responsible for coordination and monitoring and control through the California Department of Fish and Game contact person. In order to monitor vector control activities, it is estimated that 5 percent of a full-time employee would be required. Monitoring would involve determining effects of treatments on wildlife and the presence of nesting birds and coordinating permitting, documentation, and recordkeeping with the agency/agencies responsible for vector control activities.

At present, funding has not been set aside by the State for source reduction and vector control. Physical removal of vegetation would be addressed on a case-by-case basis by the pond management agencies. Mosquito production is predicted to be low from the SCH ponds and sedimentation basins. Nevertheless, if vegetation management is needed, then this contingency should be planned for, including defining action thresholds and identifying a source of funding.

F.5 Anticipated Impacts of Use

F.5.1 Monitoring

Impacts on wildlife resources resulting from monitoring activities are expected to be negligible because of the limited scale of these activities. Some disturbance related to accessing the monitoring sites is expected to occur. Adult traps would be located adjacent to the SCH ponds and sedimentation basins. Dipping for immature mosquitoes would occur on the edges of the habitats that are expected to be generally devoid of vegetative cover.

F.5.2 Treatment

Several mosquito control products are highly specific to nematoceran dipterans (i.e., mosquitoes and related flies), have no or minimal impact on non-target organisms, and are safe for wildlife and humans (Ali 1981; Boisvert and Boisvert 2000). Because mosquitoes are more susceptible to the non-persistent biological agents than are related flies such as midges (chironomids), there is a large margin of safety against potential negative food web effects provided EPA-approved application rates are followed. The non-persistent biological agents include microbial control agents, such as *Bti* and *B. sphaericus*. The *Bacillus* produce protein precursors during sporulation that, following ingestion by the mosquito larva, disrupt the integrity of mosquito digestive tract and interfere with the ability of the larva to osmoregulate.

Bacillus sphaericus has slight to practically no acute mammalian toxicity, practically no acute avian toxicity, slight to practically no acute fish toxicity, and slight aquatic invertebrate toxicity (USFWS 1984; Florida Coordinating Council on Mosquito Control 1998). Spores and toxins become suspended in the water column and retain insecticidal activity in water with high organic matter content and suspended solids. The toxicity data available indicate a high degree of specificity of *B. sphaericus* for mosquitoes, with no demonstrated toxicity to chironomid larvae at any mosquito control application rate (Lacey and

1 Mulla 1990). Therefore, risks to sensitive wildlife resources resulting from direct exposure to a single *B.*
2 *sphaericus* application and indirect food chain effects are expected to be negligible.

3 *Bti* has practically no acute or chronic toxicity to mammals, birds, fish, or vascular plants (U.S.
4 Environmental Protection Agency [USEPA] 1998). Extensive acute toxicity studies indicated that *Bti* is
5 virtually innocuous to mammals (Siegel and Shaddock 1990). These studies exposed a variety of
6 mammalian species to *Bti* at moderate to high doses and no pathological symptoms, disease, or mortality
7 were observed. Laboratory acute toxicity studies indicated that the active ingredient of *Bti* formulated
8 products is not acutely toxic to fish, amphibians or crustaceans (Garcia et al. 1980; Lee and Scott 1989;
9 Wipfli et al. 1994; Brown et al. 2000, 2002). Other ingredients such as xylene in early formulations of *Bti*
10 products were suspected to be potentially toxic (Fortin et al. 1986; Wipfli et al. 1994). Field studies
11 however indicated no acute toxicity to several fish species exposed to *Bti* (Merritt et al. 1989; Jackson et
12 al. 2002); no detectable adverse effects on breeding redwing black birds using and nesting in *Bti* treated
13 areas (Hanowski 1997; Niemi et al. 1999); and no detectable adverse effects to tadpole shrimp 48 hours
14 post *Bti* treatment (Dritz et al. 2001). Therefore, risks to sensitive wildlife resources resulting from direct
15 exposure to a single *Bti* application are expected to be negligible.

16 *Bti* activity against target and susceptible nontarget invertebrates is also related to *Bti* persistence and
17 environmental fate (Dupont and Boisvert 1986; Mulla 1990). Simulated field studies resulted in the
18 suppression of two unicellular algae species, *Closterium* sp. and *Chlorella* sp., resulting in secondary
19 effects on turbidity and dissolved oxygen of aquatic habitats, with potential trophic effects (Su and Mulla
20 1999). For these reasons, *Bti* effects on target and susceptible nontarget organisms, and potential indirect
21 trophic impacts in the field are difficult to predict. However, single applications to limited areas are not
22 expected to cause significant food chain effects. The ability for a population to recolonize a wetland
23 following multiple larvicide treatments would depend on the intensity and frequency of applications at
24 different spatial scales.

25 Pyrethrin has moderate to high acute mammalian toxicity, practically no acute avian toxicity, extreme fish
26 toxicity, and high aquatic invertebrate toxicity (USFWS 1984; USEPA 2011). The USEPA uses the Risk
27 Quotient method to estimate potential hazard to nontarget organisms. Risk quotients (RQs) are calculated
28 by dividing acute and chronic exposure estimates by ecotoxicity values for various wildlife species. RQs
29 are then compared to levels of concern (LOCs). Risk characterization provides information on the
30 likelihood of an adverse effect occurring by considering the fate of the chemical in the environment,
31 communities and species potentially at risk, their spatial and temporal distributions, and the nature of the
32 effects observed in studies. Davis et al. (2007) found that all risk quotients for nontargets (small
33 mammals, birds, as well as aquatic vertebrates and invertebrates in a pond subject to receiving the
34 chemical via drift and runoff) exposed to ULV-applied adulticides were low indicating that risks to
35 ecological receptors most likely were small. Field bioassays supported a risk assessment using actual
36 environmental concentrations indicating that a single ULV application of synergized (with PBO) or
37 unsynergized permethrin is unlikely to result in population impacts on medium- to large-bodied insects
38 (Schleier and Peterson 2010). Long-term studies over two years indicated that multiple permethrin
39 applications did not cause a reduction in terrestrial arthropods (Davis and Peterson 2008). Schleier et al.
40 (2008) found that risk quotients for aquatic species in California wildlife refuges were 0.002 or less at 1 h
41 after application, which did not exceed the USEPA risk quotient level of concern for endangered aquatic
42 organisms of 0.05. These findings suggest that the amounts of pyrethrins and PBO deposited on the
43 ground and in water after aerial ULV insecticide applications are lower than those estimated by previous
44 exposure and risk assessments (Schleier et al. 2008).

F.5.3 Threatened and Endangered Species

Permanent vegetated wetlands in the region provide habitat for the endangered Yuma clapper rail. Desert pupfish (*Cyprinodon macularius*) occasionally are found in some of the agricultural drains connected to the Salton Sea as well as in the Salton Sea. The Sonny Bono Salton Sea National Wildlife Refuge Plan does not permit adulticide applications directly over any wetland. Some drift would probably occur; however, minimal negative impacts to rails and desert pupfish from drift are expected. A study of the impacts of pyrethrin on aquatic invertebrates in wetlands on Sutter NWR indicated no decrease in total abundance of invertebrates (Jensen et al. 1999). The predominant food item of Yuma clapper rails is crayfish (*Procambarus clarkii*). It is expected that direct effects of larvicide application in the rails habitat on crayfish would be minimal. Use of bacterial larvicides in desert pupfish habitat is expected to have minimal effects on invertebrate prey used by this species and no direct toxicity effects on the pupfish. Cumulative effects of larviciding and adulticiding on clapper rails and pupfish are difficult to estimate, but it is probable that they would have minimal impact because of the expected short duration of applications, the short life time of the treatment agents in the environment and the normal quick response of insects to reinvade habitats.

F.5.4 Wetlands and Waterfowl

Migratory birds and waterfowl (geese, ducks, and coots, sandhill cranes) may be present year-round but are most abundant in wetlands and ponds from August through March (USFWS 2005). The USFWS (2005) document provides the following information on the predicted effects of mosquito control agents on the wetland fauna of the Salton Sea region and their diets.

Ducks are known to be opportunistic feeders on both plants and invertebrates, utilizing the most readily available food sources. Invertebrates, plants, and seeds compose the majority of their diet, varying with the season and the geographic location. A study in California's Sacramento Valley has shown that plant foods are dominant in fall diets of northern pintails, while invertebrate use increases in February and March (Miller 1987). Seeds of swamp timothy comprise the most important duck food in the summer-dry habitats of the San Joaquin Valley (Miller 1987). At the Kern National Wildlife Refuge, the fall diet of northern pintails and greenwinged teal was composed of over two-thirds seeds (Euliss and Harris 1987). Thus any food chain impacts resulting from larvicide and adulticide treatment would have limited impacts to the mainly seed diet of newly arriving ducks. Summer molting waterfowl are not expected to be present in the treatment area. Studies have shown that aquatic invertebrates are a dominant food of nonbreeding waterfowl during the summer molt, and the fall and winter periods (Heitmeyer 1988).

Invertebrates are also critical for egg production during the spring (Swanson et al. 1979), and duckling growth during the summer rearing period (Krapu and Swanson 1977). Mosquitoes and chironomids make an important contribution to invertebrate food resources throughout the year. Other significant food resource contributors of the invertebrate community are Coleoptera, Odonata, and Trichoptera. However, during fall flood-up of seasonal wetlands and peak mosquito populations, ducks tend to feed on seed and other plant material. Waterfowl in general tend to feed on seeds when they reach their wintering areas, perhaps to regain energy lost during long flights (Heitmeyer 1988; Miller 1987). Thus any food chain impacts resulting from larvicide and adulticide treatment would have limited impacts to the mainly seed diet of newly arriving ducks. Their diets shift to invertebrates before treatments are expected to temporarily, but substantially reduce available invertebrate food resources. Furthermore, mosquito treatments in the spring are not expected to result in limited invertebrate food resources because of the limited frequency and area of treatment in the spring.

F.5.5 Other Migratory Birds

Shorebirds, egrets, herons, as well as some gull and tern species feed in seasonal wetlands near the SCH ponds. Shorebirds feed on a wide variety of invertebrates all year, feeding which intensifies at the onset of spring migration. Field studies indicated no acute toxicity to several fish species exposed to *Bti* (Merritt et al. 1989; Jackson et al. 2002); no detectable adverse effects to breeding redwing blackbirds using and nesting in *Bti*-treated areas (Niemi et al. 1999; Hanowski 1997); and no detectable adverse effects on tadpole shrimp 48 hours post *Bti* treatment (Dritz et al. 2001). Therefore risks to other sensitive wildlife resources resulting from direct exposure to a single larvicide application are expected to be negligible.

Risk to shorebirds, egrets, herons, gulls and terns resulting from direct exposure to pyrethrins at rates used for mosquito control is expected to be negligible. Adulticide treatments are not anticipated to result in limited invertebrate food resources because of the limited area of treatment.

F.5.6 Other Wildlife

In an extensive literature review on the effects of *Bti* on mammals, Siegel and Shadduck (1990) found the bacterium innocuous. A variety of mammals were exposed to *Bti* at moderate to high doses and observed no pathological symptoms, disease or mortality. Continued use of *Bti* and *B. sphaericus* at moderate control rates are likely to have a negligible effect on mammal species on the refuge. Pyrethrin is also likely to have a negligible effect on mammals.

The actual toxicity of *Bacillus* and/or pyrethrin to amphibians and reptiles subject to direct treatment is less clear. In general, however, actual toxicity of *Bacillus* and pyrethrin to nontarget amphibians or reptiles is expected to be minimal. The target specificity of *B. sphaericus* and *Bti* for only mosquitoes should prove harmless to amphibians and reptiles and to their food supply.

Fish are not susceptible to toxic effects of *Bti* or *B. sphaericus*. Fish can be severely affected by pyrethrins when subjected to direct application. The little amount of pyrethrin that makes contact on the aquatic substrate would be immediately diluted to insignificant amounts. Also, adsorption by abundant organic matter in the target wetland would likely occur, reducing the potential for negative impacts to mosquitofish and other fish. Jensen et al. (1999) detected no mortality to mosquitofish from pyrethrin applications to seasonal wetlands on Sacramento NWR Complex.

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F.7 Personal Communications

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